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Diagnosing dehydration? Blend evidence with clinical observations

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Running Head

Diagnostic Considerations for Dehydration

27 **ABSTRACT**

28 **Purpose of Review**

29 The purpose of the review is to provide recommendations to improve clinical decision making
30 based on the strengths and weaknesses of commonly-used hydration biomarkers and clinical
31 assessment methods.

32 **Recent findings**

33 There is widespread consensus regarding treatment, but not the diagnosis of dehydration. Even
34 though it is generally accepted that a proper clinical diagnosis of dehydration can only be made
35 biochemically rather than relying upon clinical signs and symptoms, no gold standard
36 biochemical hydration index exists. Other than clinical biomarkers in blood (i.e. osmolality,
37 BUN/creatinine) and in urine (i.e. osmolality, specific gravity), blood pressure assessment and
38 clinical symptoms in the eye (i.e. tear production, palpitating pressure) and the mouth (i.e. thirst,
39 mucous wetness) can provide important information for diagnosing dehydration.

40 **Summary**

41 It is recommended that clinical observations based on a combination of history, physical
42 examination, laboratory values, and clinician experience remain the best approach to the
43 diagnosis of dehydration.

44

45 **Keywords**

46 hydration assessment, hypovolemia, fluid balance, body water, hydration status

INTRODUCTION

Adults and children continuously lose and replace body water, and often develop mild, but not clinically significant dehydration several times each week. Although very mild dehydration of 1.5 – 2 % body mass loss alters mood and results in reduced cognitive (1, 2) and physical (3) performance, it is easily corrected. When left chronically untreated, moderate-to-severe dehydration increases the risk of urinary tract infection, chronic kidney disease (4-6), and also increases medical costs, morbidity, and mortality (7). Unfortunately, despite numerous investigations (8), the methods of dehydration assessment have not been refined to the point that a single reference standard has been identified for clinical decision making (9); this magnifies the difficulty of diagnosing dehydration in clinical practice (9-12). This article provides recommendations to improve clinical decision making based on the strengths and weaknesses of commonly-used hydration biomarkers and clinical assessment methods.

Scientific evidence that informs clinical observations

We approached this problem from three perspectives: (a) rating the scientific and clinical value of hydration assessment techniques; (b) rating the time, monetary cost, and technical expertise required; and (c) incorporating the conclusions of previously published review papers. Table 1 provides a synthesis of the findings of previous publications (9, 13-16) and consensus of the present authors.

[Table 1]

There is widespread consensus regarding treatment, but not the diagnosis of dehydration. Although it is generally accepted that a proper clinical diagnosis of dehydration can only be made biochemically (e.g. using clinical laboratory tests), rather than relying upon clinical signs and symptoms (Table 1) (16), no gold standard biochemical hydration index exists (13, 16). The techniques presented in Table 1 include signs and symptoms that are frequently used in

clinical practice for screening purposes because of their relative simplicity, speed of measurement and low cost. Unfortunately, the teaching and choice of signs and symptoms are largely based on clinical experience and medical tradition (11, 16); very often, the underpinning scientific evidence supporting their use is weak (e.g., lack of comparison to a recognized criterion or reference standard). The holy grail of identifying a single gold standard hydration index is unrealistic given that the clinician evaluates different types of dehydration (e.g. hypertonic and isotonic), different severities of dehydration, and often observes a patient only once (i.e., static assessment in an emergency department), as opposed to monitoring hydration relative to a euhydrated baseline (i.e., dynamic assessment in a nursing facility). Further, the clinician accounts for the potentially confounding effects of illness and medications, and considers the desired precision, accuracy, cost, analytical time and expertise required to perform the measurement (Table 1).

Blood osmolality has been proposed as a suitable index of dehydration (typically defined as $> 300 \text{ mOsm} \cdot \text{kg}^{-1}$) (9, 12); however, this is not universally accepted (13, 17). Evidence supporting blood osmolality as a hydration index typically comes from studies that incorporate a sweat-loss model of hypertonic hypovolemia in young, fit, and healthy individuals. As such, blood osmolality is unsuitable to detect isotonic hypovolemia that often results from illness and medications (e.g., diuretics) in a clinical setting. This situation is compounded by a lack of standardization in blood osmolality measurements (calculated values versus direct measurements via osmometer, Table 1) and other clinical laboratory indices of hydration.

Guidelines for the treatment of dehydration are widely accepted, as published by the U.S. Centers for Disease Control and Prevention, the World Health Organization, the American

Academy of Pediatrics, and the National Institute for Health and Clinical Excellence of the United Kingdom. Guidelines for the diagnosis of dehydration are not universally accepted.

The decision algorithm

From the clinical perspective, volume depletion (loss of sodium from the extracellular space) and dehydration (loss of water from the intracellular space) must be distinguished because this influences the type and rate of fluid and electrolyte replacement. At this time, the evaluation for both remains largely a clinically based process incorporating the patient history, physical examination, and available laboratory values. The history and presenting circumstances often drive the decision algorithm. Confounding factors influence the decision to treat for dehydration, including intravascular volume depletion in the face of obvious total body water increase with peripheral edema on physical exam.

[Figure 1]

Clinical observations such as skin turgor, mucous membrane moisture, sunken eyes, and tear production can be helpful in children when multiple findings are present, but are not as reliable in the elderly (16). Physical examination measurements such as orthostatic blood pressure and heart rate responses support the clinical observation of dehydration. However, orthostatic changes can be difficult to obtain in a compromised patient and may reflect dilated lower extremity vasculature in an athlete post competition. Body weight can vary from day to day and is useful in the acute clinical setting when there is a reasonable baseline weight to compare to the current weight; however, variations in scales make this assessment less reliable. The admission body weight measurement provides a useful baseline to assess body fluid changes, especially when measured within a 24-h period on the same scale.

Clinical laboratory values are helpful in the context of the history and physical exam. BUN/creatinine ratio, hematocrit/hemoglobin ratio, serum sodium concentration, serum osmolality, and urine specific gravity are commonly measured in clinics, emergency departments and on the wards, but have not been validated as a reference standard. In particular, urine specific gravity reportedly is unreliable in diagnosing dehydration in children with gastroenteritis (18). Medications, especially from the diuretic classes, can confuse the biochemical picture by varying the renal clearance of water and electrolytes. Invasive procedures with central intravascular lines help establish the volume status and fluid balance of critically ill patients, but are not used in non-critical dehydration patients. Chronic kidney disease, heart failure, and other maladies that affect renal blood flow also confound the clinical picture and complicate diagnostic efforts. Recent evidence further complicates the assessment of hydration status, in that different hydration indices may validly identify dehydration in one circumstance but not another (19).

CONCLUSION

Clearly, a pressing need exists for well-controlled studies of clinically relevant dehydration models (i.e., both hypertonic and isotonic hypovolemia) in appropriate patient populations (i.e., other than athletes and military personnel) that identify hydration indices with scientific and clinical validity and precision. Only then can normal and clinically significant population ranges be determined. At present, clinical observations based on a combination of history, physical examination, laboratory values, and clinician experience remain the best approach to the diagnosis of dehydration. Figure 1 and Table 1 provide guidance to that end.

143 KEY POINTS

- 144 • Clinical observations based on a combination of history, physical examination, laboratory
145 values, and clinician experience is the best approach to the diagnosis of dehydration.
- 146 • There is widespread consensus regarding treatment, but not the diagnosis of
147 dehydration.
- 148 • There is a pressing need for well-controlled studies of clinically relevant dehydration
149 models in appropriate patient populations (i.e., other than athletes and soldiers) that
150 identify hydration indices with scientific and clinical validity and precision.

151

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157 **LEA** is currently a consultant for Drinking Water Research Foundation, Alexandria VA and
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161 Danone Research, France; has active grants with Danone Research, France; is on the
162 speaker's bureau for Danone Research, France. **NPW** has received a grant with HydraDX.
163 **WOR** None.

164

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

* of special interest

** of outstanding interest

1. Armstrong LE, Ganio MS, Casa DJ, Lee EC, McDermott BP, Klau JF, et al. Mild dehydration affects mood in healthy young women. *Journal of Nutrition*. 2012;142(2):382-8.

2. Watson P, Whale A, Mears SA, Reyner LA, Maughan RJ. Mild hypohydration increases the frequency of driver errors during a prolonged, monotonous driving task. *Physiol Behav*. 2015;147:313-8.

**The results of the present study indicated that mild hypohydration increased minor driving errors compared to euhydration. The degree of the errors were comparable to the effects observed following ingestion of an alcoholic beverage.

3. Bardis CN, Kavouras SA, Kosti L, Markousi M, Sidossis LS. Mild hypohydration decreases cycling performance in the heat. 2013;45(9):1782-9.

4. Armstrong LE. Challenges of linking chronic dehydration and fluid consumption to health outcomes. *Nutr Rev*. 2012;70 Suppl 2:S121-7.

5. Clark WF, Sontrop JM, Huang S-H, Moist L, Bouby N, Bankir L. Hydration and Chronic Kidney Disease Progression: A Critical Review of the Evidence. *Am J Nephrol*. 2016;43(4):281-92.

* This is a review on the effect of hydration in kidney health. The paper indicates that increase in water intake has beneficial effects on chronic kidney disease by suppressing vasopressin.

6. Sontrop JM, Dixon SN, Garg AX, Buendia-Jimenez I, Dohehn O, Huang S-HS, et al. Association between water intake, chronic kidney disease, and cardiovascular disease: a cross-sectional analysis of NHANES data. *Am J Nephrol*. 2013;37(5):434-42.

- 189 7. Cowen LE, Hodak SP, Verbalis JG. Age-associated abnormalities of water homeostasis.
190 Endocrinol Metab Clin North Am. 2013;42(2):349-70.
- 191 8. Cheuvront SN, Kenefick RW. Am I Drinking Enough? Yes, No, and Maybe. J Am Coll Nutr.
192 2016;35(2):185-92.
- 193 ** This review discusses the adequacy of total water intake by two different angles: avoiding
194 dehydration and balancing renal solute load.
- 195 9. Cheuvront SN, Kenefick RW, Charkoudian N, Sawka MN. Physiologic basis for understanding
196 quantitative dehydration assessment. American Journal of Clinical Nutrition. 2013;97(3):455-62.
- 197 10. Hayajneh WA, Jdaitawi H, Al Shurman A, Hayajneh YA. Comparison of clinical associations and
198 laboratory abnormalities in children with moderate and severe dehydration. J Pediatr Gastroenterol
199 Nutr. 2010;50(3):290-4.
- 200 11. Roland D, Clarke C, Borland ML, Pascoe EM. Does a standardised scoring system of clinical signs
201 reduce variability between doctors' assessments of the potentially dehydrated child? J Paediatr Child
202 Health. 2010;46(3):103-7.
- 203 12. Sollanek KJ, Kenefick RW, Walsh NP, Fortes MB, Esmaeelpour M, Cheuvront SN. Assessment of
204 thermal dehydration using the human eye What is the potential? Journal of Thermal Biology. 2012:1-7.
- 205 13. Armstrong LE. Assessing hydration status: the elusive gold standard. J Am Coll Nutr. 2007;26(5
206 Suppl):575S-84S.
- 207 14. Kavouras SA, Johnson EC, Bougatsas D, Arnaoutis G, Panagiotakos DB, Perrier E, et al. Validation
208 of a urine color scale for assessment of urine osmolality in healthy children. Eur J Nutr. 2016;55(3):907-
209 15.
- 210 * This study suggested that urine color is a valid marker to assess elevated urine osmolality in young
211 healthy children.

15. McKenzie AL, Munoz CX, Ellis LA, Perrier ET, Guelinckx I, Klein A, et al. Urine color as an indicator of urine concentration in pregnant and lactating women. *Eur J Nutr*. 2015.

* This study concluded that urine color is a valid marker of urine concentration for pregnant and lactating women.

16. Sinert R, Spektor M. Evidence-based emergency medicine/rational clinical examination abstract. Clinical assessment of hypovolemia. *Ann Emerg Med*. 2005;45(3):327-9.

17. Fortes MB, Owen JA, Raymond-Barker P, Bishop C, Elghenzai S, Oliver SJ, et al. Is this elderly patient dehydrated? Diagnostic accuracy of hydration assessment using physical signs, urine, and saliva markers. *Journal of the American Medical Directors Association*. 2015;16(3):221-8.

* This study assessed the diagnostic ability of physical, urine and saliva hydration markers in older adults. An interesting finding was that saliva osmolality had superior diagnostic utility than plasma osmolality.

18. Steiner MJ, Nager AL, Wang VJ. Urine specific gravity and other urinary indices: inaccurate tests for dehydration. *Pediatr Emerg Care*. 2007;23(5):298-303.

19. Munoz CX, Johnson EC, DeMartini JK, Huggins RA, McKenzie AL, Casa DJ, et al. Assessment of hydration biomarkers including salivary osmolality during passive and active dehydration. *Eur J Clin Nutr*. 2013.

230 **Figure 1 Legend**

231 Physical examination and laboratory measurements aid diagnosis when multiple findings exist

232

233 **Table 1 Title**

234 Comparison of research and clinical techniques to diagnose dehydration during a single

235 examination.

236

237

238 Table 1

Table 1. Comparison of Research and Clinical Techniques to Diagnose Dehydration, Using a Single Measurement.

Hydration Assessment Techniques	Patient Self-Evaluation	Cost Efficiency	Time Efficiency	Simplicity of Test	Scientific Value ^c
Signs & Symptoms					
Dry mucous membrane		●●●●●	●●●●●	●●●○○	●○○○○
Skin turgor		●●●●●	●●●●●	●●○○○	●○○○○
Nail bed refill time (sec)		●●●●●	●●●●●	●●○○○	●○○○○
Thirst sensation (thirst scale rating)	✓	●●●●●	●●●●●	●●●●●	●●●○○
Respiratory pattern		●●●●●	●●●●●	●●○○○	●○○○○
Dry axilla		●●●●●	●●●●●	●●●●●	●○○○○
Seated systolic blood pressure (mmHg)		●●●●●	●●●○○	●●○○○	●●●○○
Blood pressure change supine/upright ^a (mmHg)	✓	●●●●●	●●●○○	●●○○○	●●●○○
Heart rate change supine/upright (beats·min ⁻¹)	✓	●●●●●	●●●●●	●●●●●	●●○○○
Absence of tears		●●●●●	●●●●●	●●●●●	●○○○○
Sunken eyes		●●●●●	●●●●●	●●●●●	●○○○○
Palpated intraocular pressure		●●●●●	●●●●●	●●●●●	●○○○○
Dark urine color (color chart rating)	✓	●●●●●	●●●●●	●●●●●	●●●○○
Body mass (kg)	✓	●●●●●	●●●●●	●●●●●	●○○○○
Clinical Diagnostic Laboratory Tests					
BUN/creatinine ratio		●●●○○	●●●○○	●●●○○	●●●○○
Serum sodium concentration (mEq·L ⁻¹ or mmol·L ⁻¹)		●●●○○	●●●○○	●●○○○	●●●○○
Blood osmolality, calculated (mOsm·kg ⁻¹ or mmol·kg ⁻¹)		●●●○○	●●●○○	●●○○○	●●●○○
Hematocrit/hemoglobin ratio		●●●○○	●●●○○	●●○○○	●●●○○
Mean corpuscular volume (fL)		●●●○○	●●●○○	●●○○○	●●●○○
Urine specific gravity		●●●●●	●●●○○	●●○○○	●●●○○
Research Measurements					
Isotope dilution, total body water (L)		●○○○○	●○○○○	●○○○○	●●●○○
Neutron activation analysis, fluid volumes and ionic content		●○○○○	●○○○○	●○○○○	●●●○○
Bioelectrical impedance analysis, total body water (L)		●●●○○	●●●○○	●●○○○	●●●○○
Body mass (kg)	✓	●●●●●	●●●●●	●●●●●	●○○○○
Blood osmolality, measured ^b (mOsm·kg ⁻¹ or mmol·kg ⁻¹)		●●●○○	●●●○○	●●○○○	●●●○○
Urine osmolality (mOsm·kg ⁻¹ or mmol·kg ⁻¹)		●●●○○	●●●○○	●●○○○	●●●○○
Salivary osmolality (mOsm·kg ⁻¹ or mmol·kg ⁻¹)		●●●○○	●●●○○	●●○○○	●●●○○
Tear osmolality (mOsm·L ⁻¹ or mmol·L ⁻¹)		●●●○○	●●●○○	●●○○○	●●●○○
Intraocular pressure (mmHg)		●●●○○	●●●○○	●●○○○	●●●○○

^a lying to sitting, sitting to standing, lying to standing^b measured via freezing point depression osmometry^c considering measurement resolution, reliability and accuracy

●●●●● = high, ●●●○○ = medium & ●○○○○ = low

240 Figure 1

